Thrust, Air Pressure Rockets, and Newton's Third Law

DESCRIPTION
This lesson connects a series of activities to examine thrust and Newton's Third Law applied to rockets and cars propelled by air pressure.

OBJECTIVES
Students will

- Investigate Newton's Third Law of Motion using thrust produced by falling water, balloon powered rockets, and racing cars
- Explore the action-reaction principle by constructing a balloon-powered pinwheel
- Demonstrate how several stages of a rocket can operate in steps to propel a rocket

NASA SUMMER OF INNOVATION
UNIT
Physical Science—Forces and Motion

GRADE LEVELS
4 – 6

CONNECTION TO CURRICULUM
Science and Mathematics

TEACHER PREPARATION TIME
60 minutes

LESSON TIME NEEDED
4 hours *Complexity – Moderate*

NATIONAL STANDARDS

National Science Education Standards (NSTA)
Science as Inquiry
- Skills necessary to become independent inquirers about the natural world

Physical Science
- Position and motion of objects
- Motions and forces
- Properties of objects and materials

Science and Technology
- Abilities of technological design
- Understanding about science and technology

Common Core State Standards for Mathematics (NCTM)
Number and Operations
- Understand the place value system
- Generalize place value understanding for multidigit whole numbers

Measurement and Data
- Convert like measurement units within given measurement system
- Represent and interpret data

MANAGEMENT

The activities in this lesson should be done with cooperative groups of two to three students. Safety practices should be reviewed and observed during the activities.

Teacher will need to gather aluminum cans (or have students bring them in). For the Rocket racers, each team will need a Styrofoam tray (about 3/16 inches thick). You may request donations from your local supermarket. Other management considerations can be found in the activity pdf's.

CONTENT RESEARCH

The NASA Rockets Educator Guide has great background information on rockets and their history. The guide also discusses Newton's Laws of Motion very clearly.
http://www.nasa.gov/audience/foreducators/topnav/materials/listbytype/Rockets.html

Key Terms:

- Force: a push or a pull exerted on an object
- Thrust: when a system expels or accelerates mass in one direction the accelerated mass will cause a proportional but opposite force on that system
- Newton's First Law of Motion: States that objects at rest remain at rest and objects in motion remain in motion in a straight line unless acted upon by an unbalanced force
- Newton's Second Law of Motion: Relates force, acceleration, and mass: f = m x a. The force produced on the Newton car is directly proportional to the mass of the expelled bottle times its acceleration
- Newton's Third Law of Motion: States that every action has an equal and opposite reaction
- Stages: Two or more rockets stacked on top of each other in order to reach a higher altitude or have a greater payload capacity
- Microgravity: An environment that imparts to an object a net acceleration that is small compared to that produced by Earth at its surface

Misconceptions:

- Inertia: The most common misconception is that sustaining motion requires a continued force. (Newton's first law of motion declares that a force is not needed to keep an object in motion.) A book in motion on the tabletop does not come to a rest position because of the *absence* of a force; rather it is the presence of a force—friction—that brings the book to a rest position.

LESSON ACTIVITIES

Pop Can Hero Engine

Small student teams will construct water-propelled engines out of soft drink cans and investigate ways to in crease the action-reaction thrust produced.
http://www.nasa.gov/pdf/153414main_Rockets_Pop_Can_Hero.pdf

MATERIALS

- 4 empty aluminum soft drink cans per team (pull tabs in intact)
- Carpenter's nails of different sizes (6,12,16D)
- String (about 50cm)
- Water tub (large plastic storage tub, small kiddie pool, sink, etc.)
- Water
- Towels
- Rulers, Meter stick
- Sticker or bright permanent marker
- Wooden pencil with an eraser on one end
- Sewing pin
- 4-5" Round balloons
- Flexible soda straw
- Plastic tape
- Balloons
- 2 long party balloons (not round balloons)
- Nylon monofilament fishing line (any weight)
- 2 Plastic straws (non-bendable)
- Styrofoam cup
- Masking tape
- Scissors
- Styrofoam food trays
- Small plastic stirrer (round)
- Sandpaper

Rocket Pinwheel
Student teams construct a balloon-powered pinwheel to explore Newton's Third Law, the action-reaction principle. http://exploration.grc.nasa.gov/education/rocket/TRCRocket/rocket_pinwheel.html

Balloon Staging
Two inflated balloons are joined in a way that simulates a multistage rocket launch as they slide along a fishing line on the thrust produced by escaping air.
http://exploration.grc.nasa.gov/education/rocket/TRCRocket/balloon_staging.html

Rocket Races
Student teams construct racing cars from styrofoam food trays and power them with the thrust of an inflated balloon.
http://www.nasa.gov/pdf/153417main_Rockets_Rocket_Races.pdf

ADDITIONAL RESOURCES

- This video introduces students to Isaac Newton's Laws of Motion and demonstrates how they apply to space flight. Using the microgravity environment of Earth orbit, space shuttle astronauts conduct simple force and motion demonstrations in ways not possible on Earth:

http://quest.nasa.gov/space/teachers/liftoff/newton.html

- More on Newton's Laws from NASA Web site**:**

http://www.grc.nasa.gov/WWW/K-12/UEET/StudentSite/dynamicsofflight.html#lawofmotion

DISCUSSION QUESTIONS

- How do the concepts explored in these activities relate to NASA and its exploration of space? *Newton's laws govern in part the launch of rockets into space: inertia must be overcome in each activity, and with rockets the acceleration of a rocket is determined by its mass and the force applied to it, and rockets launch do this to the principle of action-reaction.*
- Do all three of Newton's Laws of Motion apply to the activities performed in this lesson? *Yes, all three laws apply: Inertia must be overcome for an object to move (First Law), an object's acceleration is determined by its mass and the force applied to it (Second Law), and all four activities involve motion due to the action-reaction principle (Third Law).*
- Why is the staging of rockets particularly useful to lifting equipment into space? *A large first-stage rocket once exhausted is released to return to the Earth. The upper stages are able to reach much higher altitudes because they do not have to carry the expired engines and empty propellant tanks (less mass) that make up the first stage. Space rockets are often designed with three or four stages; each fire in turn to send a payload into orbit.*

ASSESSMENT ACTIVITIES

Pop Can Hero: Ask teams to state their experiment hypotheses, explain their procedures, and present their results. Make a list of ways one can increase the number of can rotations. Have teams submit their data sheets with written conclusions.
Rocket Pinwheel: Have students explain Newton's Third Law of Motion as demonstrated by the rocket pinwheel.
Staging- Student teams should explain the performance of their "staged" rockets versus a single balloon rocket.
Rocket Racer- Review student Rocket Racer Data Sheets and Design Sheets. Have students write an explanation of Newton's Third Law of Motion using their rocket racers as examples.

ENRICHMENT

Each activity includes extensions to allow students to continue their learning experiences.

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